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Critical Minerals Emerge as Strategic Resources Driving Energy Security, Industrial Competitiveness and National Economic Sovereignty

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Recent Developments:

- Recent policy analyses have highlighted that **Critical Minerals** have become central to industrial strategy, national security and technological leadership due to their indispensable role in **clean energy, defence, semiconductors** and **digital technologies**.
- Growing geopolitical competition, concentration of mineral processing in a few countries and rising demand for energy transition technologies have elevated **critical mineral security** as a strategic policy priority for major economies.
- India has accelerated policy measures through the **National Critical Mineral Mission (NCMM)**, overseas mineral acquisitions, recycling initiatives and international partnerships to build resilient and diversified critical mineral supply chains.

Critical Minerals: The Foundation of Strategic Power:

Meaning of Critical Minerals:

- Critical Minerals** are non-fuel mineral resources that are indispensable for **clean energy technologies**, including **Electric Vehicle (EV) batteries, Solar Photovoltaic (PV) systems, wind turbines** and **grid-scale energy storage systems**.
- These minerals also serve as essential raw materials for **semiconductors, telecommunications equipment, aerospace technologies, advanced defence systems** and several high-technology manufacturing industries.
- Owing to the extreme geographical concentration of mining, refining and processing capacities, access to critical minerals has evolved beyond a commercial issue into a strategic determinant of **economic sovereignty, technological leadership** and **geopolitical influence**.
- Countries possessing secure access to critical minerals are better positioned to strengthen supply chain resilience, accelerate industrial growth and reduce strategic dependence on external suppliers.

Key Data and Statistics:

Global Refining Concentration:

- The combined global refining share of the **top three refining countries** for **copper, lithium, nickel, cobalt, graphite** and **rare earth elements** has increased to nearly **86%**, reflecting an unprecedented concentration of processing capacity.
- China** presently dominates refining activities for **19 out of 20** strategically important minerals, making it the world's leading midstream processing hub.

China's Dominance in Mineral Processing:

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- China processes more than **90%** of global **rare earth elements** and **graphite**.
- China also accounts for nearly **75%** of global **cobalt refining** and approximately **70%** of **lithium chemical processing**, creating significant supply chain dependence for many countries.

Projected Global Supply Deficits:

- Existing global project pipelines indicate that **copper** could experience nearly a **30% global supply shortfall by 2035**.
- Demand for **lithium, rare earth elements** and several battery minerals is expected to outpace supply as the global transition towards clean energy accelerates.

India's Long-Term Demand Outlook:

- Under India's **Net-Zero Emissions by 2070** pathway, cumulative demand for energy transition minerals is projected to reach approximately **169 million tonnes**.
- This projected demand is estimated to be nearly **51% higher** than demand under existing policy pathways, reflecting the rapidly expanding requirements of India's clean energy transition.

Need for Critical Mineral Security for India:

Supporting the Clean Energy Transition:

- Critical minerals are indispensable for manufacturing **solar panels, wind turbines, battery energy storage systems** and **Electric Vehicle (EV) gigafactories**, making them essential for achieving India's **Net-Zero 2070** commitment.
- Secure access to these minerals is necessary for expanding renewable energy capacity while reducing dependence on fossil fuels.

Strengthening High-Technology and Semiconductor Manufacturing:

- Critical minerals constitute essential inputs for manufacturing **semiconductors, advanced display technologies, 5G telecommunications equipment** and modern consumer electronics.
- Reliable mineral supply chains are essential for strengthening India's ambitions under the **Semicon India Programme** and expanding domestic electronics manufacturing.

Enhancing Defence and Aerospace Capabilities:

- High-strength permanent magnets, specialised alloys and rare earth materials are essential for **missile guidance systems, radars, fighter aircraft, submarines, satellites** and advanced defence equipment.
- Strengthening domestic access to critical minerals enhances India's strategic autonomy in defence production and reduces vulnerability to external supply disruptions.

Protecting Economic Sovereignty and Supply Chain Security:

- Export restrictions imposed by major producing countries, particularly on **rare earth elements** and **graphite**, demonstrate how critical minerals can be used as strategic economic instruments.
- Diversified supply sources reduce the risk of supply chain disruptions arising from geopolitical tensions, trade restrictions and resource nationalism.

Developing Domestic Midstream Industries:

- India's long-term competitiveness depends not only on securing raw mineral resources but also on establishing domestic capabilities in **smelting, chemical purification, high-purity refining** and component

manufacturing.

- Developing domestic midstream industries will enable India to capture greater value addition, reduce import dependence and strengthen industrial self-reliance.

Structural Constraints and Challenges:

Limited High-Purity Processing Infrastructure:

- Although India possesses reserves of **copper, graphite, monazite** and several other strategic minerals, it lacks adequate **midstream smelting, chemical purification** and **high-purity refining** infrastructure.
- The absence of advanced processing facilities limits domestic value addition and increases dependence on imported refined critical minerals.

Limited Exploration and Regulatory Bottlenecks:

- Mineral exploration in India remains largely confined to shallow depths, restricting the discovery of deeper strategic mineral deposits.
- Lengthy **forest clearances, environmental approvals** and limited private sector participation continue to delay the development of mining projects.
- Regulatory complexities increase project implementation timelines and reduce the pace of domestic resource development.

High Import Dependence for Critical Battery Minerals:

- India remains heavily dependent on imports for primary **lithium, cobalt** and **nickel**, which are essential inputs for domestic battery cell manufacturing.
- Such import dependence exposes India's clean energy transition and manufacturing sector to external supply disruptions and global price volatility.

Underdeveloped Recycling Ecosystem:

- Recovery of critical minerals from **electronic waste (e-waste)** and end-of-life **Electric Vehicle (EV) batteries** remains at an early stage.
- Fragmented collection systems, limited feedstock availability and evolving recycling technologies constrain the development of a circular critical mineral economy.
- The absence of a robust recycling ecosystem increases dependence on primary mineral imports.

Challenges in Developing Remote Mineral Deposits:

- Several critical mineral deposits are located in geographically remote or ecologically sensitive regions with inadequate infrastructure.
- High logistics costs, difficult terrain, environmental concerns and local socio-economic challenges increase the cost and complexity of developing upstream mining projects.

Policy Initiatives Taken So Far:

National Critical Mineral Mission (NCMM):

- The Government has approved the **National Critical Mineral Mission (NCMM)** as an integrated national framework for exploration, overseas acquisition, processing and recycling of critical minerals.
- The Mission has an overall financial outlay of **₹34,300 crore** over seven years, including Government expenditure of **₹16,300 crore** and expected investment by Public Sector Undertakings (PSUs) and other stakeholders.

- The Mission aims to undertake nearly **1,200 domestic exploration projects** by **2030–31**, while strengthening the entire critical mineral value chain.

Strategic Overseas Mineral Acquisition through KABIL:

- **Khanij Bidesh India Limited (KABIL)** has secured exploration rights over nearly **15,703 hectares** in **Catamarca Province, Argentina**, for lithium exploration and joint development.
- Overseas mineral asset acquisition seeks to diversify India's sources of critical minerals and reduce long-term import risks.
- KABIL also explores strategic partnerships with resource-rich countries for securing future supplies of critical minerals.

MMDR Act Reforms and Auction of Critical Mineral Blocks:

- Amendments to the **Mines and Minerals (Development and Regulation) Act** have empowered the Central Government to directly auction specified critical mineral blocks.
- The reforms seek to accelerate exploration, enhance transparency and encourage greater participation by private sector mining companies.
- Competitive auctions are expected to improve resource development and strengthen domestic mineral production.

Critical Mineral Recycling Incentive Scheme:

- The Government has approved a **₹1,500 crore** incentive scheme to promote recycling of critical minerals from electronic waste and end-of-life batteries.
- The scheme seeks to encourage investment in advanced recycling technologies, improve resource recovery and strengthen India's circular economy.
- Recycling is expected to become an increasingly important secondary source of strategic minerals in the coming decades.

Development of Rare Earth Processing Corridors:

- India has proposed specialised **Rare Earth Corridors** across **Odisha, Kerala, Andhra Pradesh** and **Tamil Nadu**.
- These industrial corridors aim to strengthen domestic mining, refining, processing and downstream manufacturing of rare earth products.
- Regional clustering is expected to improve economies of scale, technology adoption and industrial competitiveness.

International Strategic Partnerships:

- India has signed the **India–United States Strategic Critical Minerals Cooperation Framework** to strengthen cooperation in exploration, processing, technology transfer and resilient supply chains.
- India has also joined the **Quad Critical Minerals Initiative** to diversify trusted mineral supply networks and reduce dependence on concentrated global suppliers.
- Such partnerships seek to strengthen supply chain resilience while supporting trusted and transparent mineral value chains.

Way Forward:

Prioritising Domestic Midstream Refining:

- India should accord **infrastructure status** and targeted **Production Linked Incentive (PLI)** support to establish domestic **high-purity refining, chemical processing** and **smelting** facilities for critical minerals.

- Strengthening domestic midstream capabilities will reduce import dependence, enhance value addition and improve supply chain resilience.

Establishing Strategic Mineral Reserves:

- India should create **strategic national stockpiles** of vulnerable critical minerals, including **refined lithium, cobalt and rare earth oxides**, to cushion the economy against short-term global supply disruptions.
- Strategic reserves will enhance energy security, industrial continuity and national preparedness during geopolitical crises.

Encouraging Private Investment in Exploration:

- High-resolution **geological and geophysical data** should be made readily available to private investors to reduce exploration risks.
- A **single-window clearance mechanism**, streamlined regulatory approvals and appropriate risk-sharing financial mechanisms can accelerate private participation in mineral exploration and mining.
- Greater private investment will help unlock India's untapped critical mineral potential.

Strengthening Circular Economy through Recycling:

- **Extended Producer Responsibility (EPR)** provisions under the **Battery Waste Management Rules, 2022** should be effectively implemented to channel end-of-life batteries and urban electronic waste into organised recycling facilities.
- Developing advanced recycling technologies will improve secondary recovery of critical minerals while reducing dependence on primary mining.

Deepening Strategic International Partnerships:

- India should strengthen cooperation through initiatives such as **FORGE, Pax Silica**, the **Minerals Security Partnership (MSP)** and bilateral technology transfer agreements with trusted partner countries.
- International collaboration can facilitate access to advanced processing technologies, diversified mineral supplies and resilient global value chains.

Related UPSC Concepts:

National Critical Mineral Mission (NCMM):

- NCMM is India's integrated mission for **exploration, mining, overseas acquisition, processing, recycling** and strategic stockpiling of critical minerals.
- The Mission seeks to develop a resilient and self-reliant critical mineral value chain to support India's clean energy transition and industrial growth.

Critical Mineral Value Chain:

- The critical mineral value chain comprises **exploration, mining, beneficiation, refining, chemical processing, component manufacturing, recycling** and end-use industries.
- Countries possessing capabilities across the entire value chain derive greater economic value and strategic advantages.

Minerals Security Partnership (MSP):

- **MSP** is a multinational initiative aimed at strengthening secure, sustainable and diversified global supply chains for critical minerals.
- It promotes responsible mining, processing and investment partnerships among trusted countries.

Extended Producer Responsibility (EPR):

- **EPR** is an environmental policy approach under which producers are responsible for the collection, recycling and environmentally sound disposal of products after the end of their useful life.
- It promotes resource efficiency, circular economy practices and sustainable waste management.

Net-Zero Emissions:

- **Net-Zero Emissions** refers to balancing anthropogenic greenhouse gas emissions with their removal from the atmosphere.
- India has committed to achieving **Net-Zero emissions by 2070**, making critical minerals indispensable for expanding clean energy infrastructure.

Conclusion:

- **Critical minerals** have emerged as the foundation of modern industrial competitiveness, clean energy security, technological advancement and national strategic power.
- Although India has established important policy frameworks through initiatives such as the **National Critical Mineral Mission**, long-term success will depend upon rapidly expanding domestic **refining, processing, recycling** and advanced manufacturing capabilities.
- Converting domestic mineral resources and international strategic partnerships into globally competitive industrial capabilities will be essential for strengthening India's technological sovereignty, economic resilience and energy security.

Value Addition for UPSC:

Quick Revision Facts:

- **National Critical Mineral Mission (NCMM):** Approved with a total outlay of **₹34,300 crore** for **2024–25 to 2030–31** to strengthen the entire critical mineral value chain.
- **KABIL (Khanij Bidesh India Limited):** Joint venture of **NALCO, HCL** and **MECL** established to acquire overseas critical mineral assets.
- **Critical Minerals:** Essential for **Electric Vehicles (EVs), renewable energy, semiconductors, aerospace, defence** and advanced digital technologies.
- **China** dominates global refining of **rare earth elements, graphite, lithium** and several other strategic minerals, creating significant supply chain concentration.
- **Battery Waste Management Rules, 2022** provide the regulatory framework for **Extended Producer Responsibility (EPR)** in battery recycling.
- **Minerals Security Partnership (MSP)** seeks to build diversified, secure and sustainable global supply chains for critical minerals.
- **India's Net-Zero Target: 2070.**
- **India's Non-Fossil Electricity Capacity Target: 500 GW by 2030**, significantly increasing long-term demand for critical minerals.